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JOHN C. HERTHER
1st Lt., USAF

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Pt 4
1 Nov 1956

WS 117L ADVANCED RECONNAISSANCE SYSTEM

DEVELOPMENT PLAN

VOLUME II SUBSYSTEM PLANS

D. Guidance and Control

00920387

DOWNGRADED AT 12 YEAR
INTERVALS; NOT AUTOMATICALLY
DECLASSIFIED. DOD DIR 5200.10

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1 Nov 1956

WS 117L ADVANCED RECONNAISSANCE SYSTEM

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LOCKHEED AIRCRAFT CORPORATION

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WDSIT:

FOREWORD TO VOLUME II

The Advanced Reconnaissance System (Weapon System 117L) consists of a satellite vehicle which can perform visual, electronic, and infrared reconnaissance, together with the necessary system of ground stations, data processing centers, and training facilities.

In accordance with the instructions of CCN No. 1 to Contract AF 33(616)-3105, the Missile Systems Division, Lockheed Aircraft Corporation, has revised its Subsystem Development Plan (MSD 1536, Volume II) to be consonant with the WDD Development Plan, dated 2 April 1956, as modified and published in Volume I of this report.

It should be noted the outline of subsystems as given in MSD 1536 has been changed to agree with the WDD Plan. Subsystems H and J of MSD 1536 have been combined to give a new Subsystem H - Ground-Space Communications.

In accordance with oral instructions from WDD, the Flight Test Subsystem I of MSD 1536 has not been documented at this time. The information pertaining to flight testing is presented in the other subsystem volumes as appropriate. The titles of old Subsystems K and L (now I and J, respectively) have been changed.

OUTLINE

OF

WS 117L DEVELOPMENT PLAN

Volume I	SYSTEM PLAN
	Supplement (Top Secret)
Volume II	SUBSYSTEM PLANS
A	Vehicle
B	Propulsion
C	Auxiliary Power
D	Guidance and Control
E	Visual Reconnaissance
F	Electronic Reconnaissance
G	Infrared Reconnaissance
H	Ground-Space Communications
I	Data Processing and Intelligence Dissemination
J	Ground Support and Training

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RDB PROJECT CARD

LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION

AF-WP-L-29 MAY 53 5M

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RDB PROJECT CARD

TYPE OF REPORT

MSD-2011

REPORTS CONTROL SYMBOL DD-RDB(A)48

1. PROJECT TITLE
GUIDANCE AND CONTROL SUBSYSTEM FOR
ADVANCED RECONNAISSANCE SYSTEM
(UNCLASSIFIED)
WEAPON SYSTEM 117L

2. SECURITY ~~S~~

3. PROJECT NUMBER WS 117L-P1758

4. INDEX NUMBER

5. REPORT DATE [redacted]

6. BASIC FIELD OR SUBJECT Strategic Air Warfare

7. SUBFIELD OR SUBJECT SUBGROUP

7A. TECH. OBJ.

8. COGNIZANT AGENCY Air Research and Development Command

9. DIRECTING AGENCY
Hq ARDC
Western Development [redacted] DIVISION

OFFICE SYMBOL WDTR

TELEPHONE NO. X1393-1394

10. REQUESTING AGENCY Hq USAF

11. PARTICIPATION, COORDINATION, INTEREST
WRIGHT AIR DEVELOPMENT
CENTER

12. CONTRACTOR AND/OR LABORATORY
SEE (21)(c)
~~Lockheed Aircraft Corp.,~~
~~Missile Systems~~ Division
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CONTRACT/W.O. NO.

13. RELATED PROJECTS
WS 107A
WS 315A

14. DATE APPROVED

15. PRIORITY 1A

16.

17. EST. COMPL. DATES
RES.
DEV.
TEST
OP. EVAL.

18. FY	FISCAL ESTS. (M $)

19.

20. REQUIREMENT AND/OR JUSTIFICATION

20 a. The guidance and control subsystem is required to provide the following functions:

1. Inertial guidance for the satellite from takeoff to a ~~circular~~ DESIRED orbit, ~~at the prescribed altitude [illegible]~~

~~2. Correction signals to the attitude control system and to the orbital boost phase to obtain accurate speed and direction for a prescribed circular orbit.~~ DESIRED

~~3. Attitude control during non-powered flight and control during orbital boost phase by use of autopilot and control motors.~~

2. Attitude control of vehicle orientation in orbit for maximum ~~visual~~ reconnaissance ~~resolution~~. [illegible]

3. ATTITUDE INDICATION TO PROVIDE FOR GEOGRAPHIC ~~LOCATION~~ CORRELATION OF RECONNAISSANCE DATA.

22. RDB SN CN IC & P X. I. C.

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R&D PROJECT CARD
CONTINUATION SHEET

SECURITY CLASSIFICATION

MSD-2011

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
GUIDANCE AND CONTROL SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	S	WS 117 L
	4.	5. REPORT DATE 1 November 1956

21 a. Brief and Operational Characteristics

This subsystem will provide the means for guidance and control of the orbiting vehicle so as to place it in a ~~circular~~ DESIRED orbit ~~at approximately 300 n. miles~~ above the surface of the earth. In addition, the subsystem will operate in an orbit attitude control mode to stabilize the vehicle and to provide a platform suitable for mounting reconnaissance elements.

The attitude will be stabilized in order to prevent image motion AND DISTORTION OR LOSS OF DATA. from degrading resolution of visual data. The attitude must also be known with sufficient accuracy to permit the application of navigation location techniques to the data gathered.

b. Approach

Ascent guidance will be accomplished by self-contained inertial guidance equipment similar to that being developed for the WS 107 A and WS 315 A programs. Autopilot control will be that furnished with the booster vehicle used.

Attitude stabilization during the orbiting phase is derived from the differential gravity torques acting on the mass distribution of the vehicle with damping provided by means of rate SENSING gyros and motor driven inertia wheels.

The effects of the environment on the sensing instruments will constitute one of the major problems in this development program. Every effort will be made to take advantage of the information, EQUIPMENT, and test results from the WS 107 A and WS 315 A programs.

c. Tasks of the Subsystem

TASK #

1. a. Ascent Guidance ~~Package~~

~~b.~~ [redacted]

c. During the period from launch to cut-off of the boost engines, the vehicle will be guided by a self-contained inertial guidance system, which consists of a gyro stabilized platform, singly integrating accelerometers, and a guidance computer. The design of the platform gimbals,

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SECURITY CLASSIFICATION

MSD-2011

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
GUIDANCE AND CONTROL SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	S	WS 117 L
	4.	5. REPORT DATE 1 November 1956

gyros, and accelerometers and the computer programming will be similar to those under development for the WS 107 A and WS 315 A programs.

At the end of boost the ascent guidance ~~package~~ SUBSYSTEM will furnish information on the missile's position and velocity to the transition computer.

During the coast phase after termination of boost the gyro platform will sense the attitude of the vehicle and furnish control signals to the transition control system.

2. WS 107A-1 AUTOPILOT

3. a. Transition Computer

b. ~~Subcontract and~~/OR ~~LAC MSD~~

c. During the coast phase the transition computer will compute the time to fire the ~~final stage~~ VERNIER BOOST propulsion and the velocity to be gained both in magnitude and direction. This information will be used to orient the vehicle in the desired attitude for final boost and to furnish initial conditions for the ~~orbital~~ VERNIER boost guidance.

4. a. Transition Control System

b. Contractor: LAC MSD

c. During the coast period a control system is required to reorient and stabilize the combined booster-~~ARS stage~~ OSU (ORBIT STAGE VEHICLE) ~~vehicle~~ in the correct attitude for ~~orbital~~ VERNIER boost. Commands to this unit ~~come~~ ARE DERIVED from the ascent guidance unit.

5. a. ~~Orbital~~ VERNIER Boost Guidance

b. ~~Subcontract~~

c. This unit provides guidance signals to the OSV autopilot, measures the velocity gained during orbital boost, and provides a signal to cut off the engine. Some components of this sytem may be common to the ascent guidance unit or the orbital attitude control system.

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SECURITY CLASSIFICATION

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1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
GUIDANCE AND CONTROL SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	S	WS 117 L
	4.	5. REPORT DATE 1 November 1956

6 a. OSV Autopilot

~~b. Contractor: LAC MSD~~

c. The orbit stage autopilot provides for dynamic control of thrust direction in order to maintain the vehicle in a controlled attitude during the final stage thrust acceleration. This unit derives its commands from the orbital boost guidance unit.

7. a. ~~Orbital~~ Attitude Control

~~b. Subcontract and LAC MSD~~

c. The orbital attitude control unit is designed to align and maintain the alignment of the vehicle to the local vertical of the earth's gravitational field during the orbital life of the vehicle.

Attitude control on orbit will be achieved by a mass distribution of the vehicle which will make the desired orientation a naturally stable one about three orthogonal axes. Since this constitutes an essentially undamped dynamic system, damping will be provided by means of angular rate sensing devices and motor-driven inertia wheels. Rough initial alignment to the local vertical will be accomplished after orbital boost. BY JET REACTION

8. a. Attitude Indication and Image Motion Compensation

~~b. Subcontract and/or LAC MSD~~

c. An indication of the instantaneous vehicle attitude may be necessary in order to correlate reconnaissance data with geographical location. This may be accomplished by a combination of internal measurements and an external reference. The indication outputs are presented to the data transmission system.

Body rotations of the vehicle will cause blurring of the image of ground objects if the attitude control is insufficient to permit maximum use of system resolution. It may be necessary to compensate for these rotations by attitude sensing and control of the optical pickup system.

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MSD-2011

1. PROJECT TITLE GUIDANCE AND CONTROL SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	2. SECURITY OF PROJECT ~~S~~	3. PROJECT NUMBER WS 117 L
	4.	5. REPORT DATE 1 November 1956

21 d. Other Information

The environment in which the guidance and control equipment must operate is of paramount importance and influences the accuracy and operability of the systems and components. Advantage will be taken wherever possible of the environmental test facilities that have been established for the WS 107 A and WS 315 A programs. Tests of components and subsystems under those programs will be followed closely wherever applicable.

21 e. Background History

Work on guidance and control for a satellite vehicle has been conducted at MIT, North American Aviation Inc., and the RAND Corp. These studies have indicated the feasibility of ascent guidance and orbital attitude control of a satellite.

Work on the inertial guidance systems for WS 107 A and WS 315 A is of direct interest to the ARS project for the fields of ascent guidance, environmental effects, and component development and testing.

21 f. Future Plans

NOTE: See System Development Plan GUIDANCE + CONTROL MILESTONES

~~The establishment of subcontracts for the various tasks in guidance and control with qualified contractors will be initiated in the near future.~~

~~Investigation of the feasibility and accuracy of autopilot guidance for early test flights will be initiated.~~

~~Procurement of some components in preproduction quantities and testing of them will be initiated.~~

~~Investigations of various methods of control actuation during coast and immediately after orbital boost will be continued.~~

21 g. References

1. Monthly and Quarterly Reports of Project Pied Piper. ~~(S)~~
2. Progress Reports Nos. 1 through 5 AND FINAL REPORT on Air Force Contract AF 33(616)-2039 "Guidance and Attitude Control Study" MIT Instrumentation Laboratory. ~~(S)~~

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1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
GUIDANCE AND CONTROL SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	~~S~~	WS 117 L
	4.	5. REPORT DATE 1 November 1956

3. Progress AND FINAL Reports on Air Force Contract AF 33(616)-2137 "Guidance and Attitude Control Study" North American Aviation Inc. Autonetics Division. ~~(S)~~

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TABS

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~~SUBSYSTEM D~~ - GUIDANCE AND CONTROL SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM, WS117L

~~Tab 1~~ - General Design Specification

~~I. GENERAL~~

A. Statement of Problem

The objective of the Guidance and Control Subsystem is to ensure the thrust is applied in such a way that the vehicle is placed in a circular orbit at an altitude of 300 n. miles. At this altitude the vehicle velocity must be in a horizontal plane and its magnitude must be approximately 25,500 ft/sec ($v = \sqrt{gR}$). When the vehicle enters the orbit the error in velocity must not exceed 30 feet per second in magnitude and 1 milliradian in direction. If these conditions are met, a 300-n. mile orbit will have maximum and minimum altitudes of 320 and 280 n. miles, respectively. After the orbiting condition has been obtained and the engines have been shut down, the guidance and control subsystem converts to an attitude control mode of operation. The vehicle attitude must be controlled so as to stabilize the line of sight with respect to a known reference frame to permit reconnaissance read-in and read-out.

B. Approach

The operation of the ARS guidance and attitude control systems can be divided into four phases:

1. The booster-powered phase beginning at launch and continuing to the cutoff of the booster and sustainer engines.
2. The unpowered coast to apogee on an elliptical ascent trajectory.
3. The application of the orbital powered boast to provide the necessary increment of velocity to place the vehicle on the desired orbit.
4. Attitude stabilization and indication after the orbit stage vehicle has been established on the desired orbit.

C. Solution

1. Booster-Powered Phase

The initial booster-powered phase is very similar to that of the intercontinental and intermediate range ballistic missiles. Hence advantage can be taken of the development of booster vehicles including propulsion, airframe, autopilot and control system, and guidance, for the ballistic missile projects, WS 107A and WS315A.

An inertial guidance system consisting of a gyro-stabilized platform, singly integrating accelerometers, and a guidance computer will provide steering signals to the booster autopilot and propulsion cutoff signals for the rocket engines.

2. Coast Phase

After termination of the main boost propulsion, the vehicle the required attitude. In addition, the orbital boost guidance system will measure the velocity gained by means of an integrating accelerometer and will furnish the propulsion cutoff signal when the required velocity is attained.

4. Attitude Stabilization

After termination of the orbital boost, the ~~OSV~~ SATELLITE must be reoriented roughly to the local vertical so that the vehicle will stabilize in attitude through the action of the earth's gravitational field on the mass distribution of the vehicle. THIS WILL REQUIRE THAT THE MOMENTS OF INERTIA OF THE ORBITING NEEDS TO BE UNEQUAL AND ROUGHLY IN THE RATIO OF 10:9.6:1 FOR THE PITCH, ROLL AND YAW (~~ABOUT VERTICAL~~ AXES). Through the operation of rate gyros sensing the vehicle's angular motion and the action of motor-powered flywheels, the oscillations of the vehicle's angular motion will be damped to a stable orientation with respect to the local gravitational vertical (including orientation about the vertical as the yaw axis).

Torques disturbing the stable orientation of the OSV to the vertical may arise during orbiting because of the oblateness of the earth, elliptical orbiting, non-compensated torques from rotating machinery, radiation torques from the APU, etc. Since damping is provided in the orbital attitude control, the angular motion resulting from these disturbances will always be damped out (provided the disturbing torques are not too large). THIS DICTATES THAT ALL TORQUES FROM INTERNAL MACHINERY BE COUNTERBALANCED AND THAT THE NET TORQUE RESULTING FROM IMPERFECT COUNTERBALANCE BE SMALL.

Because the attitude control system time constant is large, a~~n~~ CONTINUOUS indication of the instantaneous attitude may be necessary to PROVIDE A REFERENCE IN THE VEHICLE FROM WHICH TO COMMAND OFFSET ANGLES OF SENSING ELEMENTS IN THE ADVANCED PROGRAMS.

correlate ~~reconnaissance data with geographical location~~ and to ~~compensate for image motion in the optical pickup system~~. This could be accomplished by means of an external reference (e.g., horizon sensor or sun tracker) or internally by gyro means, or by a combination of both.

II. DESCRIPTION

A. Tasks

1. Ascent Guidance

This task requires the provision of an inertial guidance package to guide the vehicle during boost and to furnish attitude stabilization information during the coast phase. Because of the latter requirement, a ground-linked radio guidance system such as that being developed for the Atlas ballistic missile is not sufficient, although its use may be of some benefit during boost.

It is anticipated that the inertial guidance package will consist of a three-axis platform stabilized by three single-axis gyros, three single-axis integrating accelerometers mounted on the platform, and a guidance computer. The outputs from the guidance equipment during boost will be steering signals to the boost autopilot which is assumed to be furnished with the booster vehicle, a propulsion cutoff signal to the rocket engines, and information to the transition computer on the measured position and velocity at the end of boost.

During coast the stable platform furnishes attitude information to the transition control system.

Ground equipment for initial alignment of the inertial system and for monitoring the operation of the guidance equipment will be required.

It is anticipated that significant advantage can be taken of the guidance development work on the WS 107A and WS 315A programs in the utilization of developed components and environmental test facilities and test results.

2. Transition Computer

During the transition coast period a computer is required which accepts data from the ascent guidance equipment and computes the velocity magnitude to be gained during the orbital boost stage, the time to initiate the orbital boost, and the proper attitude for the OSV during orbital boost.

It is anticipated that the transition computer can operate on the basis of deviations from a preset program. Hence its accuracy is not critical, and it can be a relatively simple analogue type computer.

3. Transition Control System

Attitude control must be exercised whenever the rocket engines are not operating. During the coast or transition phase of the trajectory, the residual angular impulse during and after termination of the booster propulsion and that due to booster separation must be removed, and the attitude must be stabilized for proper thrust orientation prior to initiation of the orbital boost.

Attitude sensing information inputs to the transition control system are derived from the gyro-stabilized platform and from the transition computer. The torques necessary to control and stabilize the attitude can be obtained by means of small auxiliary gas jets or by means of motor-controlled inertia flywheels.

4. Orbital Boost Guidance

During the orbital boost phase it is necessary to provide steering signals to the OSV autopilot and a propulsion cutoff signal to the rocket engine. The orbital boost guidance system must sense the attitude of the vehicle and provide steering signals to the OSV autopilot control system to maintain the proper thrust attitude. In addition, it must measure the velocity gained during orbital thrust, compare this with the velocity-to-be gained computed by the transition computer, and provide a cutoff signal to the rocket engine when the two are equal.

The attitude sensing function can best be provided by means of gyroscopes, and the velocity gained can be measured by means of an integrating accelerometer oriented along the thrust axis of the vehicle.

Some of the components of the orbital boost guidance system may be common to the ascent guidance system or the orbital attitude control system.

5. OSV Autopilot

Thrust will be applied to the OSV in a direction parallel to the horizontal plane at the apogee. This thrust will be applied for about 30 seconds prior to apogee so that a measured increase is made to the vehicle horizontal velocity while no vertical velocity component is added. The vehicle heading is established to provide the proper value of the maximum latitude for the orbit.

The OSV autopilot provides the dynamic control of thrust direction through deflections of two gimballed 150-pound thrust control engines. This control is required to maintain a stable vehicle attitude during the OSV boost stage. Since this unit functions at very high altitude and after the OSV has already gained a high velocity, the primary requirement on it is that it be capable of providing stable flight control. Through reference to the attitude reference unit, the autopilot receives error signals required to correct initial errors in a short time and to ensure that thrust is applied in the proper direction to avoid large residual vertical velocity components at the end of the boost stage.

6. Orbital Attitude Control

During orbiting flight the vehicle attitude must be controlled so that payload elements will be aligned properly for reconnaissance purposes. The directions of lines-of-sight, antenna axes, etc., must be controllable, and, in some cases, they must be known within accurate limits.

The reference direction for alignment is the local vertical of the earth's gravitational field. By proper distribution of the mass of the vehicle, the desired orientation can be made a naturally stable one about three orthogonal axes through the action of the gravitational field gradient in producing restoring torques on the vehicle. Oscillations of the vehicle about the stable orientation are undamped. In order to provide damping so that the oscillations will die out with time, a means of sensing the rates of angular motion, such as rate gyros, will provide signals to control electric motors driving inertia wheels.

After the orbital boost stage, the vehicle must be aligned roughly to the local vertical before the orbital attitude control becomes effective. This can be accomplished by means of small auxiliary air jets controlled by the stabilization elements of the orbital boost guidance system.

Some components of the orbital attitude control system may be shared with the orbital boost guidance system.

7. Attitude Indication and Image Motion Compensation

Disturbing torques on the orbiting vehicle due to the oblateness of the earth, the effect of an elliptical orbit, residual unbalance in rotating machinery, etc., will cause transitory and steady-state oscillations despite the presence of damping. An indication of the instantaneous attitude of the vehicle may be necessary in order to correlate reconnaissance information with geographical location. Changes in attitude will be available from the rate gyros of the orbital attitude control equipment, but drifts in the gyros will limit the long-term accuracy. Use of an external reference, such as the earth's horizon or astronomical bodies, e.g., the sun, can provide an absolute reference for attitude indication.

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Subsystem D - GUIDANCE AND CONTROL

Tab 2 Summary - Subsystem Milestones

1 Flight Test Schedules
2 (for reference)
3
4 I Engineering Prototype Tests
5
6 II Pioneer Visual
7
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10 Guidance & Control System Schedules
11
12 Ascent Guidance
13 First A-C Platform
14 First Ascent Guidance System
15
16 First Lightweight System
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18 Transition Computer
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20 Transition Control System
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22 Orbital Boost Guidance
23
24
25 OSV Autopilot
26
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28 Orbital Attitude Control System
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30
31 Attitude Indication and Image
32 Motion Compensation
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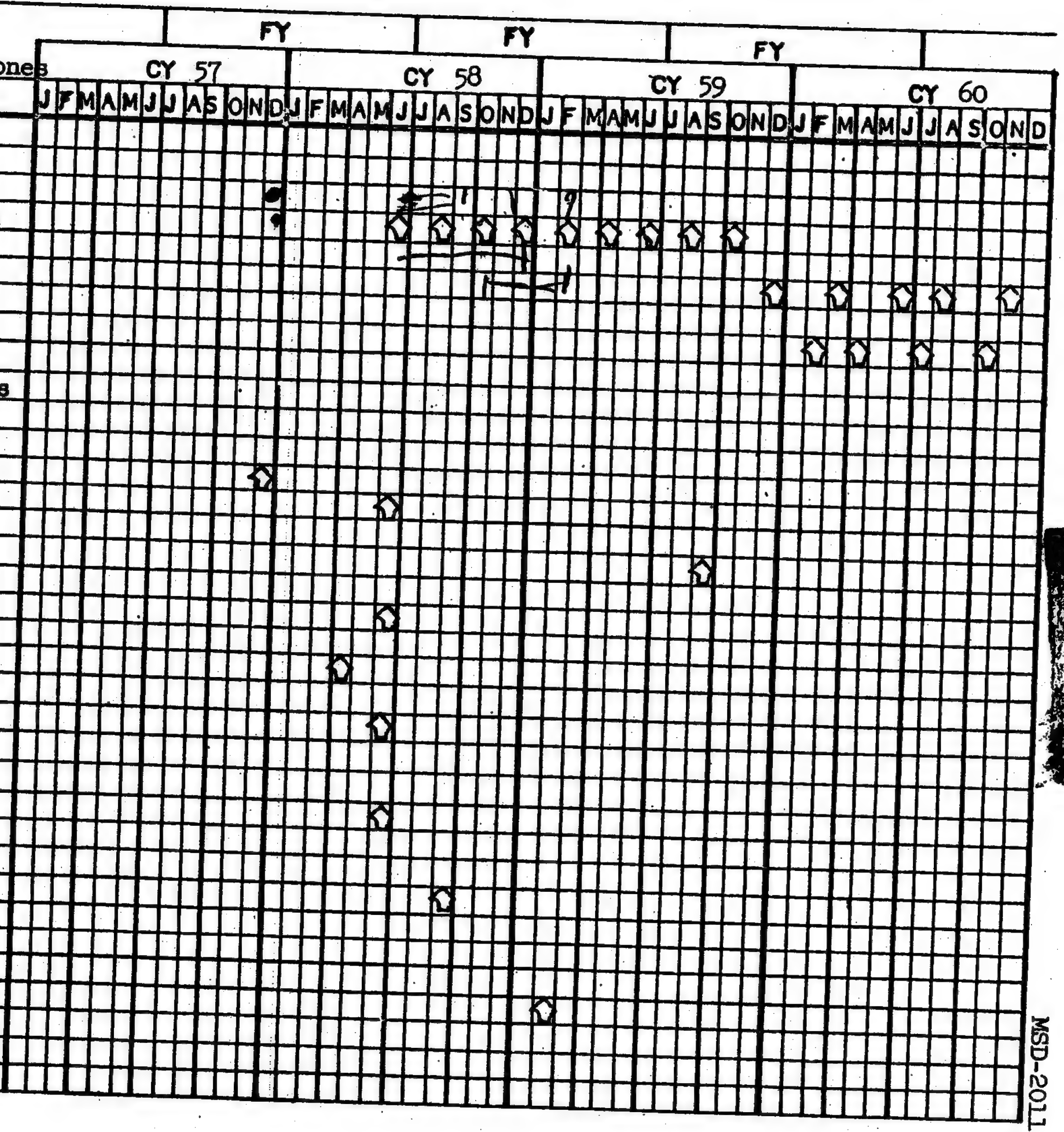
34
35



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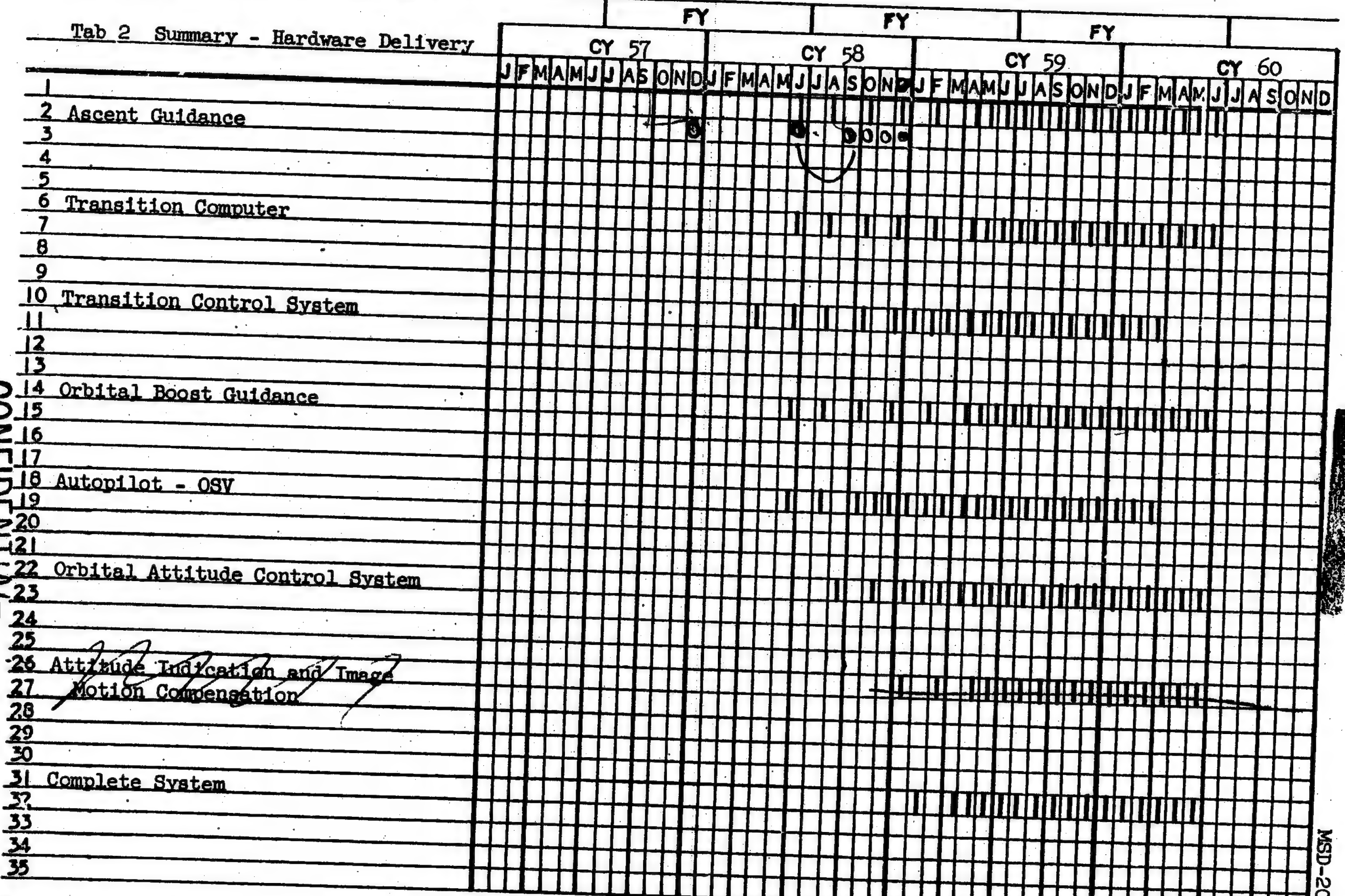
Subsystem D - GUIDANCE AND CONTROL

Tab 2 Summary - Hardware Delivery



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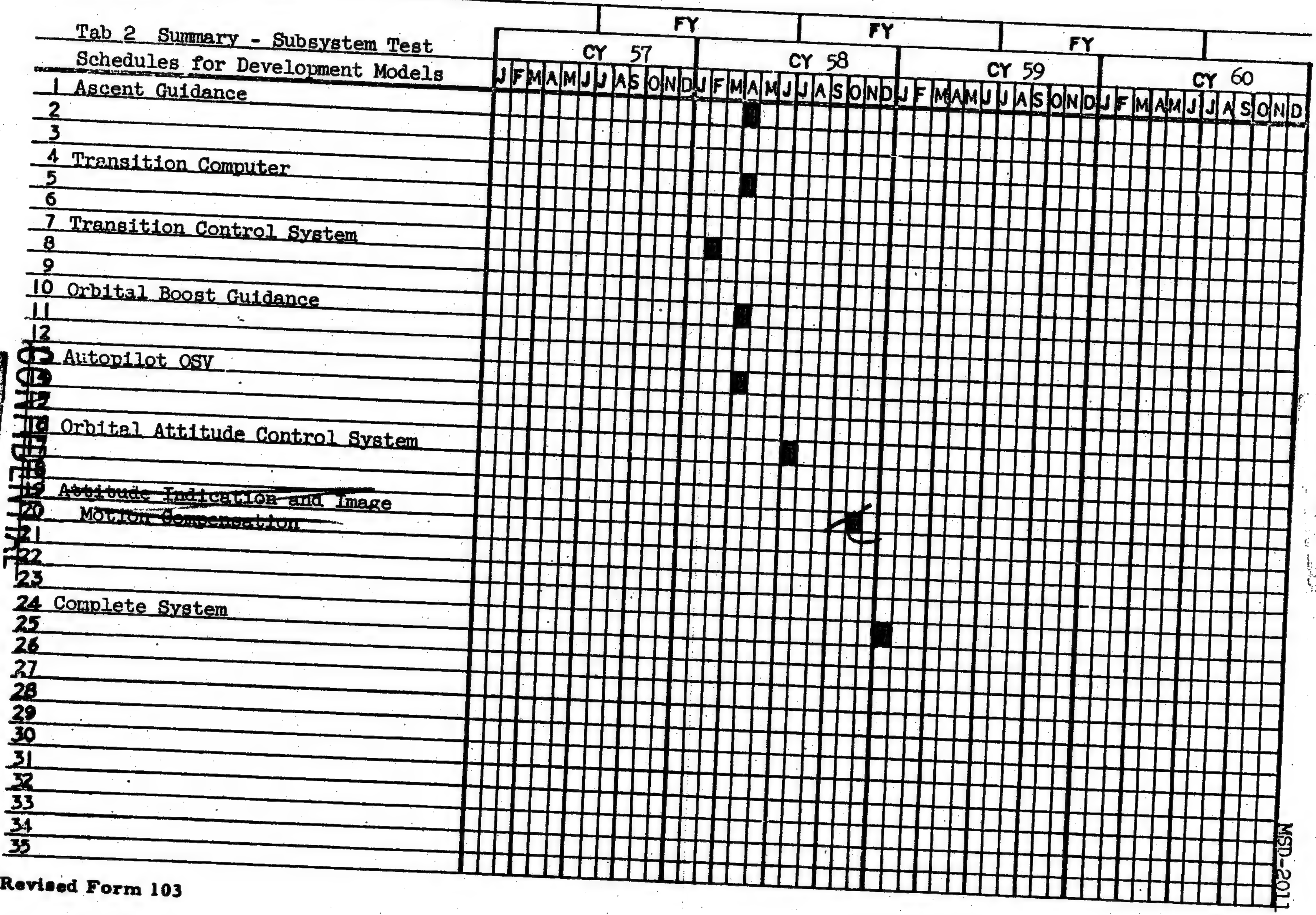
Subsystem D - GUIDANCE AND CONTROL

Tab 2 Summary - Subsystem Test Schedules for Development Models



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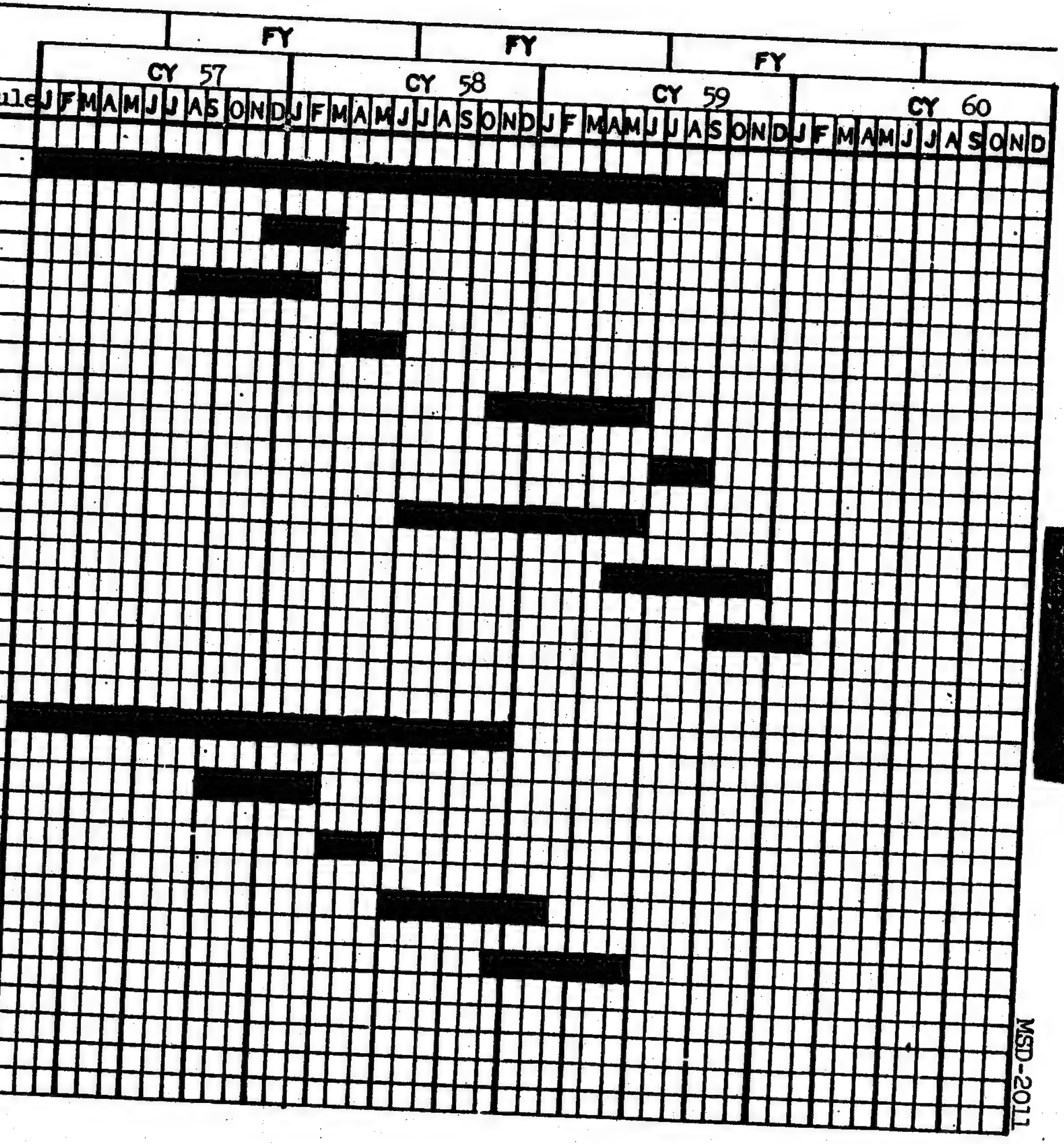
Subsystem D - GUIDANCE AND CONTROL

Tab 2 Summary - Research and Development Schedule



1 Ascent Guidance Task
2 A. Research and Development
3
4 B. Tests of A-C Platform
5
6 C. Fabrication of Computer
7
8 D. Tests of Interim System
9
10 E. Fabrication of Lightweight
11 System Development Model
12 F. Tests of Lightweight System
13
14 G. Components Prod. Prototype
15 Fabrication
16 H. Fabrication of Lightweight
17 Prototype Models
18 I. Tests of Lightweight
19 Prototype Models
20
21 Transition Computer Task
22 A. Research and Development
23
24 B. Fabrication of Develop. Model
25
26 C. Tests of Development Model
27
28 D. Fabrication of Prototype Models
29
30 E. Tests of Prototype Models
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35

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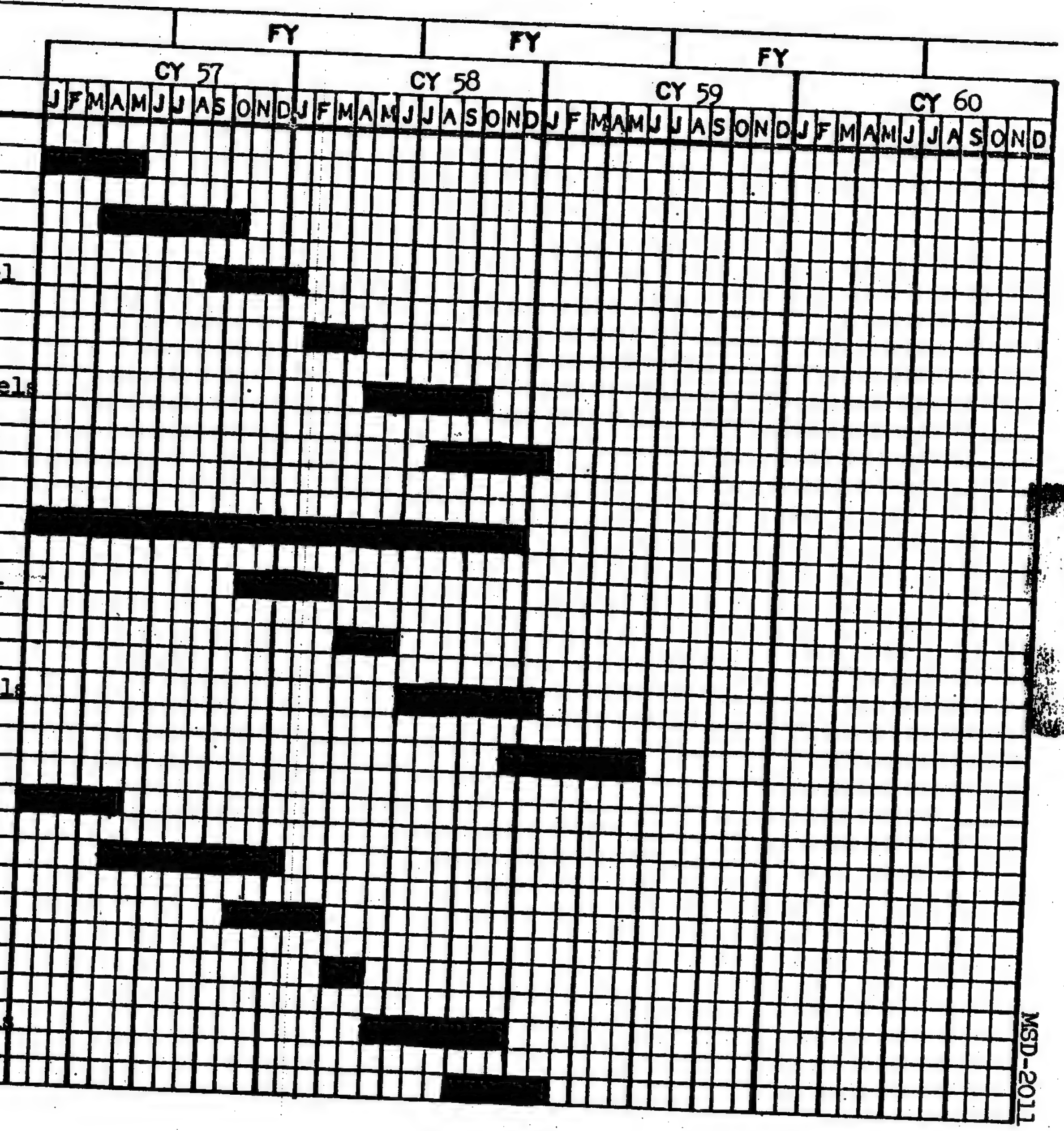
O INITIAL GROUND TEST [illegible]
P INTEGRATION WITH FMSI F116.

Subsystem D - GUIDANCE AND CONTROL

Tab 2 Summary - R & D Schedule
(Continued)



1 Transition Control System Task
2 A. Requirement Study
3
4 B. Research and Development
5
6 C. Fabrication of Develop. Model
7
8 D. Compliance Tests
9
10 E. Fabrication of Prototype Models
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12 F. Tests of Prototype Models
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14 Orbital Boost Guidance Task
15 A. Research and Development
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19 C. Tests of Develop. Model
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21 D. Fabrication of Prototype Models
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24 OSV Autopilot
25 A. Requirement Study
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29 C. Fabrication of Develop. Model
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31 D. Compliance Tests
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33 E. Fabrication of Prototype Models
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35 F. Tests of Prototype Models

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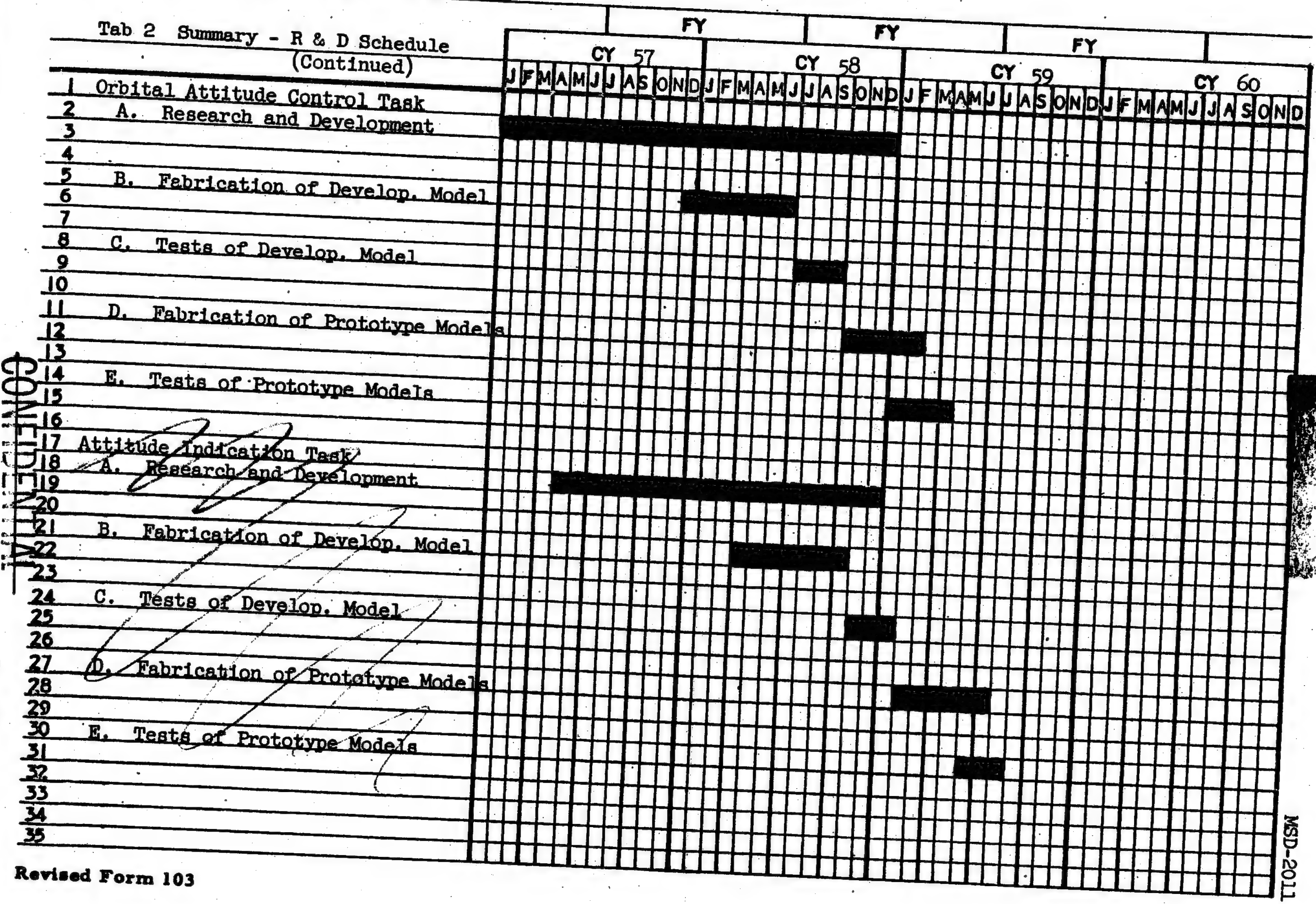
Subsystem D - GUIDANCE AND CONTROL

Tab 2 Summary - R & D Schedule (Continued)



1 Orbital Attitude Control Task
2 A. Research and Development
3
4
5 B. Fabrication of Develop. Model
6
7
8 C. Tests of Develop. Model
9
10
11 D. Fabrication of Prototype Models
12
13
14 E. Tests of Prototype Models
15
16
17 Attitude Indication Task
18 A. Research and Development
19
20
21 B. Fabrication of Develop. Model
22
23
24 C. Tests of Develop. Model
25
26
27 D. Fabrication of Prototype Models
28
29
30 E. Tests of Prototype Models
31
32
33
34
35

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☒ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 12 PAGES

3. DATE 1 November 1956

4. TITLE Ascent Guidance and Transition Computer ~~(Acceptance Tests)~~

5. INITIAL ☒ CHANGE

6. NUMBER WS 117L

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj) ARS

10. CONTRACTOR Subcontractor

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY ~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1	Stable Platform with Computers (Complete)	Functional tests with specified inputs	Subcontractor	Oct 58	Nov 58
2	Stable Platform with Computers (Complete)	Functional tests with simulated vehicle flight	Subcontractor	Nov 58	Dec 58
3	Stable Platform with Computers (Complete)	Compatibility tests with transition control system	MSD Research Lab.	Dec 58	Jan 59
4	Stable Platform with Computers (Complete)	Flight Test*	AFMTC	Jan 59	Jun 59

*About 6 units are required.

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TEST CENTER APPROVAL

20. NAME ORGANIZATION

21. NAME ORGANIZATION DATE

DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 12 PAGES

3. DATE 1 November 1956

4. TITLE Ascent Guidance and Transition Computer (Environmental Tests)

5. INITIAL ☒ CHANGE

6. NUMBER WS 117L

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj) ARS

10. CONTRACTOR Subcontractor

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY ~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
5	Stable Platforms with Computers (Complete)	Shock & vibration tests and Temperature Tests	Subcontractor	Jul 58	Nov 58

TEST CENTER APPROVAL

20. NAME ORGANIZATION

21. NAME ORGANIZATION DATE

DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 12 PAGES

3. DATE 1 November 1956

4. TITLE Transition Control System (Development Tests)

5. INITIAL ☒ CHANGE

6. NUMBER WS 117L

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj) ARS

10. CONTRACTOR Lockheed MSD

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY ~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1	System (Complete)	Response Tests (Simulated Load)	MSD Research Lab.	Aug 58	Sep 58
2	System (Complete)	Functional Tests with transition computer and simulated vehicle flights.	MSD Research Lab.	Dec 58	Jan 59
3	System (Complete)	Flight Tests*	AFMTC	Sep 58	Jun 59

*About 8 units are required.

TEST CENTER APPROVAL

20. NAME ORGANIZATION DATE

21. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

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R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 12 PAGES

3. DATE 1 November 1956

4. TITLE Transition Control System (Environmental Tests)

5. INITIAL ☒ CHANGE

6. NUMBER WS 117L

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj) ARS

10. CONTRACTOR Lockheed MSD

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY ~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1	System Complete	Shock & Vibration Tests and Temperature Tests	MSD Research Lab.	Aug 58	Sep 58

TEST CENTER APPROVAL

20. NAME ORGANIZATION DATE

21. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

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R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 12 PAGES

3. DATE 1 November 1956

4. TITLE Orbital Boost Guidance (Acceptance Tests)

5. INITIAL ☒ CHANGE

6. NUMBER WS 117L

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj) ARS

10. CONTRACTOR Subcontractor

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY ~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1	Guidance Unit	Functional Tests with specified input signals	Subcontractor	Aug 58	Sep 58
2	Guidance Unit	Functional Tests with simulated vehicle flight	Subcontractor	Sep 58	Nov 58
3	Guidance Unit	Compatibility Tests with OSV autopilot (Simulated vehicle)	Subcontractor or MSD Research Lab.	Aug 58	Sep 58
4	Guidance Unit	Flight Tests*	AFMTC	Nov 58	Jun 59

*About 6 required for flight tests.

TEST CENTER APPROVAL

20. NAME ORGANIZATION

21. NAME ORGANIZATION DATE

DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 12 PAGES

3. DATE 1 November 1956

4. TITLE Orbital Boost Guidance (Environmental Tests)

5. INITIAL ☒ CHANGE

6. NUMBER WS 117L

7. RESP CENTER	8. PROJECT OFFICER	9. SUPPORTS (Sys or Proj)	10. CONTRACTOR	11. CONTR NR	12. PRIORITY AND PREC	13. SECURITY
		ARS	Subcontractor			~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1	Guidance Unit	Shock and vibration tests and temperature tests	Subcontractor	Sep 58	Oct 58

TEST CENTER APPROVAL

20. NAME ORGANIZATION DATE

21. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 12 PAGES

3. DATE 1 November 1956

4. TITLE OSV Autopilot (Development Tests)

5. INITIAL ☒ CHANGE

6. NUMBER WS 117L

7. RESP CENTER	8. PROJECT OFFICER	9. SUPPORTS (Sys or Proj)	10. CONTRACTOR	11. CONTR NR	12. PRIORITY AND PREC	13. SECURITY
		ARS	Lockheed MSD			~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1	Autopilot	Response Tests (Simulated Load)	MSD Research Lab	Jul 58	Aug 58
2	Autopilot	Vibration and temperature tests (Simulated load)	MSD Research Lab	Aug 58	Sep 58
3	Autopilot	Simulation Tests (Simulated vehicle)	MSD Research Lab	Sep 58	Oct 58
4	Autopilot	Flight Test*	AFMTC	Sep 58	Jun 59

*About 6 units required for (OSV)

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TEST CENTER APPROVAL

20. NAME	ORGANIZATION	DATE
21. NAME	ORGANIZATION	DATE

RESPONSIBLE CENTER APPROVAL

22. NAME	ORGANIZATION	DATE

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R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 12 PAGES

3. DATE 1 November 1956

4. TITLE OSV Autopilot (Environmental Tests)

5. INITIAL ☒ CHANGE ☐

6. NUMBER WS 117L

7. RESP CENTER	8. PROJECT OFFICER	9. SUPPORTS (Sys or Proj)	10. CONTRACTOR	11. CONTR NR	12. PRIORITY AND PREC	13. SECURITY
		ARS	Lockheed MSD			~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1	Autopilot (OSV)	Shock & vibration tests and temperature tests	MSD Research Lab	Aug 58	Sep 58

TEST CENTER APPROVAL

20. NAME	ORGANIZATION	DATE

21. NAME	ORGANIZATION	DATE

RESPONSIBLE CENTER APPROVAL

22. NAME	ORGANIZATION	DATE

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1. **R & D TEST ANNEX** ☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER						2. REPORTS CONTROL SYMBOL PAGE 1 OF 12 PAGES
4. TITLE Orbital Attitude Control (Acceptance Tests)				5. INITIAL ☒ CHANGE		3. DATE 1 November 1956
7. RESP CENTER	8. PROJECT OFFICER	9. SUPPORTS (Sys or Proj) ARS	10. CONTRACTOR Subcontractor	11. CONTR NR	12. PRIORITY AND PREC	6. NUMBER WS 117L 13. SECURITY ~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1	Attitude Control Unit	Response to specified input signal	Subcontractor	May 58	Jun 58
	Attitude Control Unit	Frequency response tests for specified input signals (Units in conjunction with mathematical vehicle)	Subcontractor	May 58	Jun 58
	Attitude Control Unit	Compatibility Tests with orbital boost guidance	Subcontractor	Jun 58	Jul 58
	Attitude Control Unit	Flight Tests*	AFMTC	Aug 58	Jun 59

* Approximately 7 units required

	TEST CENTER APPROVAL	
20. NAME	ORGANIZATION	
21. NAME	ORGANIZATION	DATE
	RESPONSIBLE CENTER APPROVAL	DATE
22. NAME	ORGANIZATION	DATE

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 12 PAGES

3. DATE 1 November 1956

4. TITLE Orbital Attitude Control (Environmental Tests)

5. INITIAL ☒ CHANGE

6. NUMBER WS 117L

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj) ARS

10. CONTRACTOR Subcontractor

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY ~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1	Attitude Control Unit	Shock, vibration, and temperature tests	Subcontractor	Jul 58	Aug 58

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TEST CENTER APPROVAL

20. NAME ORGANIZATION DATE

21. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

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R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 12 PAGES

3. DATE 1 November 1956

4. TITLE Attitude Indication (Development Tests)

5. INITIAL ☒ CHANGE

6. NUMBER WS 117L

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj) ARS

10. CONTRACTOR Lockheed MSD

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY ~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1	Attitude Indication Unit	Response Tests to specified input signals	MSD Research Lab	Nov 58	Feb 59
2	Image Motion Compensation Unit*	Response Tests to specified input signals	MSD Research Lab	Dec 58	Feb 59
3	Attitude Indication Unit	Flight Tests** (OSV)	AFMTC	Mar 59	Jun 59

*If needed in photographic system.
**About 3 units would be required.

TEST CENTER APPROVAL

20. NAME
ORGANIZATION
DATE

21. NAME
ORGANIZATION
DATE

RESPONSIBLE CENTER APPROVAL

22. NAME
ORGANIZATION
DATE

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 12 PAGES

3. DATE 1 November 1956

4. TITLE Attitude Indication (Environmental Tests)

5. INITIAL ☒ CHANGE

6. NUMBER WS 117L

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj) ARS

10. CONTRACTOR Lockheed MSD

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY ~~Secret~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1	Attitude Indication Unit	Vibration & Temperature Tests (Environmental Tests)	MSD Research Lab	Feb 59	Mar 59
2	Image Motion Compensation Unit*	Vibration & Temperature Tests (Environmental Tests)	MSD Research Lab	Feb 59	Mar 59

*If needed in photographic system.

TEST CENTER APPROVAL

20. NAME ORGANIZATION DATE

21. NAME ORGANIZATION DATE

RESPONSIBLE CENTER APPROVAL

22. NAME ORGANIZATION DATE

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1.

R & D TEST AND TEST SUPPORT AIRCRAFT ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 1 PAGES

3. DATE 1 November 1956

4. TITLE Subsystem D - GUIDANCE AND CONTROL

5. INITIAL ☒ CHANGE

6. NUMBER WS 117 L

7. ITEM NUMBER	8. AIRCRAFT REQUIRED			9. ASG CODE	10. MOD REQD	11. DATE REQD AND LOCATION	12. ESTIMATED RELEASE DATE	13. RECOMMENDED DISPOSITION	14. F HRS F CST	15. EST COST
	QTY	TYPE, MODEL AND SERIES	SERIAL NUMBER							

AIRCRAFT WILL NOT BE REQUIRED FOR TESTS OF GUIDANCE AND CONTROL SUBSYSTEM

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1.

R & D MATERIEL ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 2 PAGES

3. DATE ~~1 November 1956~~

4. TITLE GUIDANCE AND CONTROL SUBSYSTEM FOR ARS, WS 117L

5. INITIAL ☑ CHANGE

6. NUMBER WS 117L – P1758

7. MATERIEL REQUIREMENTS (Indicate Items in Columnar Form using Columns as cited in Examples)

MATERIEL	UNIT COST	ESTIMATED COST (APPROX)	FY NEED DATE
(1) Medium Precision Analog Computer*			
60 Operational Amplifiers			1957
8 Function Generators	2000	16,000	1957
6 Multipliers	833	5,000	1957
2 Recorders (4 Channel)	3500	7,000	1957
2 Signal Generators (Audio Oscillators)	500	1,000	1957
2 Intercommunication System to Controls Lab.			1957
3 ~~Orbital~~ Attitude Control System Simulation Test Stand		8,000	1958
4 Attitude Indication System		5,000	1958
5 Transition Control System T st Stand		5,000	1957
6 OSV Autopilot Load Simulation Test Stand		5,000	1957

*Required to support, controls development and simulation at MSD Research Lab. This equipment will not be part of the MSD computer facility.

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1.

R & D MATERIEL ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 2 OF 3 PAGES

3. DATE
1 ~~November 1956~~

4. TITLE
GUIDANCE AND CONTROL SUBSYSTEM

5. INITIAL ☒
CHANGE

6. NUMBER
WS 117L

7. MATERIEL REQUIREMENTS (Indicate Items in Columnar Form using Columns as cited in Examples)

GAS: 1177

MATERIEL	~~ESTIMATED~~ COST (APPROX.)	FY NEED DATE
7 Gyro Rate Table (0.01° per sec to 1200° per sec) Servo Drive, 25-50 pound capacity, built in stroboscopic unit	50,000	1958
8 Tilt Table (0.01%)	(5,000)	1957
Rate Table (0.01%)	10,000	1958
10 Equatorial Drift Test Stand (0.01%)	(5,000)	1957
11 /Scorsby Test Table (0.01%	2,400	1957
WS 315A AIRBORNE ASCENT GUIDANCE ~~UNITS~~ @ 200K		
12 ~~[illegible]~~ 1 UNIT BY DEC 1957	200~~K~~ 000	~~DEC 57~~
13 12 UNITS @1/MONTH BEGINNING ~~SEPT~~ 1958 @ 200 ~~800~~	2,400~~K~~ 000	~~SEPT 58~~
14 WS 315A GROUND SUPPORT EQUIPMENT 2 COMPLETE SETS @ 300~~K~~ 000	600~~K~~ 000	~~TOTAL~~ FY 58

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MISSILE SYSTEMS DIVISION

1.

R & D MATERIEL ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 3 OF 3 PAGES

3. DATE 1 November 1956

4. TITLE COMPUTER FACILITY

5. INITIAL ☐ CHANGE

6. NUMBER WS 117L

7. MATERIEL REQUIREMENTS (Indicate Items in Columnar Form using Columns as cited in Examples)

MATERIEL	ESTIMATED COST (APPROX.)	NEED DATE
1. High Precision Analog Computer*		
96 Operational Amplifiers		
8 Servo Resolvers (Precision)		
20 Multipliers (Servos)		
10 Electronic Multipliers		
2 X-Y Plotters (Small)		
1 X-Y Plotter (Large)		
10 Function Generators		
40 Amplifiers		
8 Servo Multipliers		
5 Diode Function Generators		
2 - 4-Channel Recorders		
2. Digital Computer Facility* already planned for MSD RESEARCH LAB. (Fall 1956)		

*This requirement is subject to correlation with other programs and equipment.

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SUBSYSTEM D - GUIDANCE AND CONTROL

DATE

ITEM: MSD - "INPLANT" TEST FACILITY*
SYSTEMS TEST FACILITY*

USING AGENCY:

LOCATION:

BUDGET CONTROL ESTIMATE:

NEED DATE:

SCHEDULE:	1956						1957												1958												1959											
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D

DESCRIPTION AND UTILIZATION:

* Complete description of the facilities is given in TAB 6 -- Subsystem J - Ground Support and Training.

REMARKS:

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Subsystem D - Guidance and Control
Tab 7 - R & D Contract Funds

(in thousands of dollars)	FY 57				FY 58		Quarters		FY 59				FY 60			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
LAC																
(1) Research & Development	56	137	208	273	336	368	403	428	418	377	329	334	199	209	234	254
(a) Sub Contracts	140	300	410	410	410	300	300	300	300	250	250	250	250	200	200	200
(2) Fabrication	0	0	109	186	186	215	279	318	318	240	235	235	183	266	232	385
(a) Purchased Components	20	40	160	495	495	525	655	726	726	520	520	520	355	486	399	644
Sub Total	216	477	887	1369	1427	1408	1637	1772	1762	1387	1334	1339	987	1161	1065	1483
Fee	22	48	89	136	143	141	164	177	176	139	133	134	99	116	107	148
TOTAL *	238	525	976	1500	1570	1549	1801	1950	1939	1526	1467	1473	1086	1277	1172	1631
Total Fiscal Year			1739			6420				6882				5008		

*Differences in Totals due to rounding

Subsystem D - Guidance and Control
Tab 7 - R & D Contract Funds (cont'd)
(in thousands of dollars)

	FY 61				FY 62		Quarters		FY 63					
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	TOTALS *
LAC															
(1) Research & Development	269	259	249	239	204	194	201	206	206	206	127				6,923
(a) Sub Contracts	200	150	150	150	150	100	100	100	100	50	50				5,770
(2) Fabrication	430	368	384	419	312	346	317	453	579	136	0				7,131
(a) Purchased Components	720	600	630	692	551	612	549	791	1001	239	0				13,671
Sub Total	1619	1377	1413	1500	1217	1252	1167	1550	1886	631	177				33,465
Fee	162	138	141	150	122	125	117	155	189	63	18				3,354
TOTAL *	1781	1515	1554	1650	1339	1377	1284	1705	2075	694	195				36,849
Total Fiscal Year			6481				5650				4669				

*Differences in Totals due to rounding.

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Subsystem D - Guidance and Control
Tab 8 - R & D Manpower Annex

WORK ITEM	Type of Manpower	Quarters 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
LAC Research & Development	1-2-3*	9	27	40	52	64	70	79	84	82	74	66	67	40	42	47	51
LAC Fabrication & Assembly	4	0	0	30	51	51	59	79	90	90	68	68	68	53	77	67	111
TOTAL		9	27	70	103	115	129	158	174	172	142	134	135	93	119	114	162
*Average																	
40% Type 1 Scientific & Technical																	
50% Type 2 Engineering Support																	
10% Type 3 Management & Administration																	

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Subsystem D - Guidance and Control
Tab 8 - R & D Manpower Annex (cont'd)

WORK ITEM	Type of Manpower	Quarters 17	18	19	20	21	22	23	24	25	26	27	28	29	30	** TOTALS
LAC																
Research & Development	1-2-3*	54	52	50	48	41	39	40	41	41	41	25				1,366
LAC																
Fabrication & Assembly	4	124	106	111	121	90	100	91	130	166	39					2,040
TOTAL		178	158	161	169	131	139	131	171	207	80	25				3,406
*Average																
40% Type 1 Scientific & Technical																
50% Type 2 Engineering Support																
10% Type 3 Management & Administration																
**Total in Man Quarters																